Research Statement

Brian M. Donovan

Overview

For over a century, people have argued that it is pointless to intervene to reduce social inequality because racial or gender differences are genetically determined. My research program explores how these beliefs are learned in school biology, and whether they can be unlearned when students construct complex understandings of genetics in order to refute prejudiced beliefs. I call this kind of education a *humane genetics education*, because its purpose is to help students identify and change prejudiced beliefs about social groups that are prevalent in western culture. The instructional frameworks of a humane genetics education emphasize scientific argumentation, model-based reasoning, and quantitative reasoning and they are designed using theories that describe the social psychology of prejudice (Dar-Nimrod & Heine, 2011; Lynch et al., 2018), the situated nature of conceptual change (Brown et al., 1989; diSessa, 2018; Lave, 1991), and the difficulties of using scientific information to debias individuals (Lewandowsky et al., 2012). To explore how genetics education influences beliefs about social identity, I conduct field research that employs randomized control trials (RCTs), quasi-experimental designs, and qualitative research methods. To analyze data produced by such studies, I use item response theory, linear mixed-modeling, population average models, and content analysis. Insights from my research have begun to show how biology education affects the development of prejudice and how to design a more humane biology education.

Dissertation

Racial differences in genetic disease prevalence are a core component of genetics curricula (Morning, 2011). My dissertation investigated if text-based instruction on racial differences in genetic disease prevalence affected belief in genetic essentialism, which is a social-cognitive bias implicated in prejudice and stereotyping (Dar-Nimrod & Heine, 2011). Genetic essentialists believe that genes make individuals of the same social group physically and behaviorally uniform and different groups physically and behaviorally discrete (Andreychik & Gill, 2014). People who believe in the genetic uniformity of social category members have been found to believe that stereotypes apply to all members of a group (Yzerbyt et al., 2001). When people believe that social groups are biologically discrete categories they also tend to endorse stereotypes (Bastian & Haslam, 2006) because discreteness beliefs facilitate category-based inductions about group members (Gelman, 2004). Finally, when people believe there are inherent differences in the genes of groups, they attribute cognitive and behavioral differences between groups to genetics because believing that groups cohere around inherent characteristics accentuates uniformity and discreteness beliefs (Yzerbyt et al., 2001). Therefore, if learning affects the belief that social groups are genetically discrete and/or the belief that individuals of the same group are genetically uniform, it could affect stereotyping through genetic essentialism. My dissertation explored the plausibility of this mechanism.

Published in *Science Education* (Donovan, 2015), the first chapter of my dissertation used genetic essentialism theory (GET) (Dar-Nimrod & Heine, 2011) to argue that racial terminology in the biology curriculum can increase belief in genetic essentialism of race during adolescence by affecting causal reasoning and social categorization. At Stanford, I designed and conducted three double-blinded field experiments (i.e. RCTs) to test this hypothesis. The first study, published in the *Journal of Research in Science Teaching (JRST)*, was carried out in eighth grade classrooms in a private school in San Francisco (Donovan, 2014). Students ($N = 43$) were assigned at random to read about the prevalence of human genetic diseases with or without racial terminology and they responded to items in two validated measures of genetic essentialism of race. Students in the racial condition agreed significantly more with items in both measures of genetic essentialism than students in the nonracial condition. Next, I sought to replicate these findings in a sample of public high school students in the San Francisco Bay Area ($N = 86$). Published in *Science Education* (Donovan, 2016), the results of this RCT replicated the findings of the first. Given these results, I hypothesized that repeated exposure to racial terminology in the biology curriculum would have a cumulative impact on belief in genetic essentialism of race by leading students to perceive more genetic variation between races and less genetic variation within races. To test this hypothesis, I conducted a three-month long, double-blinded RCT, which was published in *JRST* (Donovan, 2017). Individual students from Bay Area schools (N = 135, 7-9th grades) were randomly assigned within their classrooms to learn from a curriculum discussing racial differences in skeletal structure and the prevalence of genetic diseases or from an identical curriculum that lacked racial terminology. Students in the racial condition grew significantly more in belief in genetic essentialism compared to students in the nonracial condition over the three-month course of study. Compared to the nonracial condition, students in the racial condition also grew significantly more in the *misperception* that there is more genetic variation between races than there is within them. These findings suggested that when students learn about the prevalence of specific genetic diseases in particular racial groups it could unintentionally lead students to make two incorrect inferences that strengthen belief in genetic essentialism. The first is that, if each group has its own special disease, then people of the same race must be highly uniform. The second is that, if disparate groups suffer from different diseases, then racial groups must be categorically different. For this paper, I received the 2017 *National Science Teacher Association Research Worth Reading Award*.

Current Research Program on Humane Genetics Education

Race. Findings from my dissertation suggested that when biology education increases the perception that races are genetically different it can increase prejudice. But, is the converse also possible? That is, when people learn that there is, in fact, more genetic variation within races than there is between them, then can such learning reduce racial bias? I am

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now exploring this question as the PI of a NSF funded grant "Towards a More Human(e) Genetics Education: Exploring how Knowledge of Genetic Variation and Causation Affects Racial Bias among Adolescents" (NSF CORE award # 1660985, USD $1.29 million). This project uses intervention learning materials that engage students in quantitative reasoning, model-based reasoning, and scientific argumentation to help them make sense of human variability and its causes. My research team then studies how students learn with these materials to produce mechanistic knowledge about how genetics education affects social cognition of race. Using this knowledge, we then revise our learning materials.

The first study from this project was recently published in *Science Education* (Donovan, Semmens, et al., 2019), and it received "the most downloaded paper award" for this journal. In this study, my team randomized 8th and 9th grade students (N = 166) into separate classrooms to learn for an entire week either about the topics of: (i) human genetic variation; or (ii) climate variation. In a cross-over randomized trial with clustering, we demonstrated that the human genetic variation intervention significantly reduced perceptions of between group genetic variation and significantly increased perceptions of within group variation, which in turn caused a significant decrease in belief in genetic essentialism and stereotyping. We then replicated these findings in two more RCTs, one with adults (N = 176) and another with biology students (N = 721, 9th-12th graders). Statistically, we have found that our humane genetics learning materials cause reductions in belief in genetic essentialism by increasing student understanding of genetic variation, and these reductions are amplified for students who possess more multifactorial genetics knowledge (Donovan, Weindling, Salazar, et al., 2020).

To better understand the cognitive basis of these statistical findings, my research team recently finished a comparative case analysis of cognitive think-alouds with our intervention materials (N = 21, 8th graders). We found that students scoring higher on assessments of quantitative reasoning and multifactorial genetics knowledge activate and apply more prior knowledge over time while they are interacting with our learning materials. This process allows these students to leverage more of the affordances in the learning materials to construct the understanding that there is more genetic variation within racial groups than between them, which lowers their belief in genetic essentialism. A recently accepted paper in the *Journal of Research in Science Teaching* describes these findings in more detail (Donovan, Weindling, Salazar, et al., 2020) and corroborating results for this hypothesis can be read in a quasi-experiment that my lab published recently in the journal *Science & Education* (Donovan, Weindling, & Lee, 2020).

Currently, my lab is analyzing data from focus groups with students to understand if and how knowledge about race gained through a humane genetics education influences how students make sense of race-related phenomena outside of the biology classroom. We are also analyzing video data to explore how teachers help students to make sense of race and genetics through our humane genetics learning materials. Additionally, my lab is analyzing data from a within-teacher cluster-randomized trial (Donovan & Weindling, n.d.)*,* where half of each teacher's classrooms (N = 7 teachers, n = 20, classrooms) were randomly assigned to learn from our humane genetics curriculum and the other half learned from the teacher's business as usual (BAU) genetics curriculum. This study was pre-registered in the Registry of Efficacy and Effectiveness Studies and it was the subject of a front-page article in *The New York Times* on December 8th, 2019 (Harmon, 2019). After genetics learning concluded, we found that classrooms using the humane genetics curriculum had greater genomics literacy (*Cohen's d* = 0.24, *p* = 0.001), greater interest in socializing with different races (*d* = 0.18, *p* = 0.013), and greater belief in institutional racism (*d* = 0.17, *p* = 0.001) than classrooms using a BAU genetics curriculum. Humane genetics classrooms also had lower perceptions of genetic variation between races (*d* = -0.69, *p* = 0.001), lower genetic attributions for racial difference (*d* = -1.68, *p* = 0.001), and less belief in genetic essentialism (*d* = -0.59, *p* = 0.001) relative to BAU classrooms. However, there was no treatment effect on colorblind racism (*d* = 0.018, *p* = 0.32) suggesting that the humane genetics curriculum did not backfire to create a new form of racism after reducing a different form of racism. All of these treatment effects were driven by pre-post changes over time in the humane genetics treatment condition (and not the BAU control) and they were robust to statistical controls for pre-tests, social desirability bias, classroom ordering effects, grade level, and whether a classroom was honors/Advanced Placement.

Moving into the future, my humane genetics research program on race is growing into the domain of undergraduate genetics education through a new 1.3 million-dollar NSF IUSE grant that I received with my collaborator, Michelle Smith (Cornell University). Currently, I have another 4.5 million-dollar NSF grant under review with the NSF DRK-12 competition, which, if funded, will explore different teaching strategies to mitigate against identity threat and motivated reasoning among students while they learn with a humane genetics curriculum. We will also explore how teachers help students to construct anti-essentialist understandings of human difference. The new DRK-12 proposal is a collaboration with Robbee Wedow (Harvard/MIT) and Ravit Duncan (Rutgers University).

Gender. My humane genetics research program is now moving into the domain of gender essentialism, too. Recently, I published a field experiment that explored how the content of the genetics curriculum on sex differences affects the development of beliefs about science ability through its impact on genetic essentialism of gender (Donovan, Stuhlsatz, et al., 2019). Students (N = 460, 8th -10th grade) were randomized to read a genetics text that: (i) explained plant sex differences; (ii) explained human sex differences; or (iii) refuted genetic essentialism of gender. Relative to students in the refutational condition, students in the two sex conditions (plant and human) grew significantly more in their belief in genetic essentialism and also in their belief that science ability is innate. Structural equation modeling of the data

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demonstrated that the effect of the readings on the belief that science ability is innate was mediated by genetic essentialism and this indirect effect was significant for girls but not boys. In turn, the belief that science ability is innate predicted lower future interest in STEM for girls, but not for boys. In a re-analysis of this data, my lab also showed how these findings were driven by a cognitive conflation between the sex concept and the gender concept in the writing of students (Stuhlsatz, Buck Bracey, & Donovan, 2020). We argue that if genetics education helps students to distinguish and problematize these concepts then it might be possible to reduce gender stereotyping through genetics education, and possibly mitigate against gender disparities in STEM by increasing social belonging in STEM. I recently received a $2 million-dollar NSF grant to extend this line of research with Catherine Riegle Crumb (UT Austin) and Andrei Cimpian (NYU). One area of research that we will explore through this new grant is whether and how our genetics education interventions promote the social belonging of women of color in STEM fields, and if they help to reduce disparities in STEM belonging for women of color by creating a more inclusive and less threatening learning environment for these students.

Conclusion. My work contends that biology education affects how people make sense of social inequality by interacting with social cognitive biases about race and gender. In particular, my research shows that genetics education has the power to increase or decrease prejudiced beliefs about social groups when it influences beliefs about the uniformity of a social group, the discreteness of social groups, and/or the genetic basis of social identity. Findings from my research could help us to understand how to design a more humane biology education–one that improves scientific reasoning about complex biological phenomena in order to reduce social-cognitive biases that perpetuate social inequality. Over the next five to seven years, I plan to continue my ongoing research efforts and also extend my research and development efforts in humane biology education. New avenues of research I intend to explore are whether it is possible to change how students think about environmental injustices and climate justice issues by influencing how students conceptualize political groups and races. This line of research will build upon pilot experiments currently being conducted by research assistants in my learning lab and it will be informed by publications about ecology education and environmental injustices (Donovan et al., 2014) and climate change education (Zummo, Busch, & Donovan, 2020) that I have already published. In the coming years, I hope to integrate this work with my scholarship on humane genetics education in order to articulate a research-based framework for a more humane biology education—an education that reduces racial and gender disparities in STEM fields by actively teaching students about the flaws of racist and sexist arguments that are used to justify inequality.